JOURNAL OF

FORESTRY

NOVEMBER 1968

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The Pines of Cedros and Guadalupe Islands

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ABSTRACT.—The pines of Cedros and Guadalupe Islands are related to Monterey pine (Pinus radiata) *and bishop pine* (P. muricata). *They are of interest and possible value in their own right, and as sources of additional genetic variation for breeding programs with Monterey and bishop pine. Preliminary tests indicate a significantly greater resistance of the pines of both islands to* Dothistroma pini, *compared with mainland Monterey pine. This paper describes the islands, the pine populations on the islands, and the history and location of known plantations of pines from the islands. The Guadalupe Island population includes essentially no young trees, and is in danger of extinction. One tree is of larger diameter than any known native Monterey pine or bishop pine. In general, the diameters of mature trees observed on Cedros Island were much smaller than those of mature trees on Guadalupe, although the heights of the tallest trees on the two islands are nearly identical.*

MONTEREY PINE (*Pinus radiata* D. Don) is one of the most widely planted tree species in the world, currently occupying over 600,000 hectares of plantation (*29*). The Forest economies of New Zealand, Chile, and Australia rely heavily on Monterey pine, and it is a frequent component of both landscape and forest plantings in most Mediterranean-climate countries. These countless trees ultimately trace their origin back to three native populations on the coast of California, located at approximately 37°, 36½°, and 35½° north latitude, and occupying a total area of less than 8,000 hectares. In spite of this small native range, Monterey pine is a highly variable species and thus susceptable to genetic manipulation.

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This expedition was supported by the New Zealand Forest Research Institute, the Associates in Tropical Biogeography of the University of California, and the Wrasse Foundation of the University of California. Handling the collected seed and care of the seedlings was supported by National Science Foundation Genetic Biology Grants 2550 and 5053 and the New Zealand F.R.I.

Bishop pine (*P. muricata* D. Don) occurs in seven widely separated populations on or near the coast of California and Baja California, from approximately 41° to 31½° north latitude. It also occurs on Santa Cruz and Santa Rosa Islands (34° north latitude, near Santa Barbara) where the *remorata* form is in particularly high frequency (*18*). Although bishop pine is used in Christmas-tree, ornamental, and shade plantings, its use as a timber or pulp species is relatively unimportant compared to Monterey pine.

The pines of Guadalupe Island have been recognized as close relatives of Monterey pine since their botanical discovery in 1875 (*30*). The pines of Cedros Island, first named in 1888, have been considered more closely related to bishop pine (*13*). Newcomb (*25*) and Fielding (*9*), however, have recently reported that both Cedros Island pine and Guadalupe Island pine are much more like Monterey pine than like bishop pine in several characteristics.

Both islands have repeatedly been visited by biologists since 1890. If plantings of seedlings were established from these early collections, no records are today available. In 1964, only a few small outplantings of living trees were established and only five trees were older than 10 years. Therefore, proposed relationships of these island pines to Monterey pine and bishop pine, and speculations on the possible usefulness of these pines in forestry, are based on observations in the native populations, herbarium specimens, and a few young trees planted in Australia, New Zealand, and California.

All the trees of known Cedros or Guadalupe origin planted prior to 1964 have been traced to four collections from Guadalupe Island and two collections from Cedros Island. One of the Cedros collections was from a single tree. The earliest Guadalupe collection is known to have come from the island, but there is uncertainty about the location of the sampled trees within the population, and about the number of trees sampled. The other Cedros collection and two of the Guadalupe collections were each made from several trees, with the general area of origin within the populations identified. However, little information is avail-

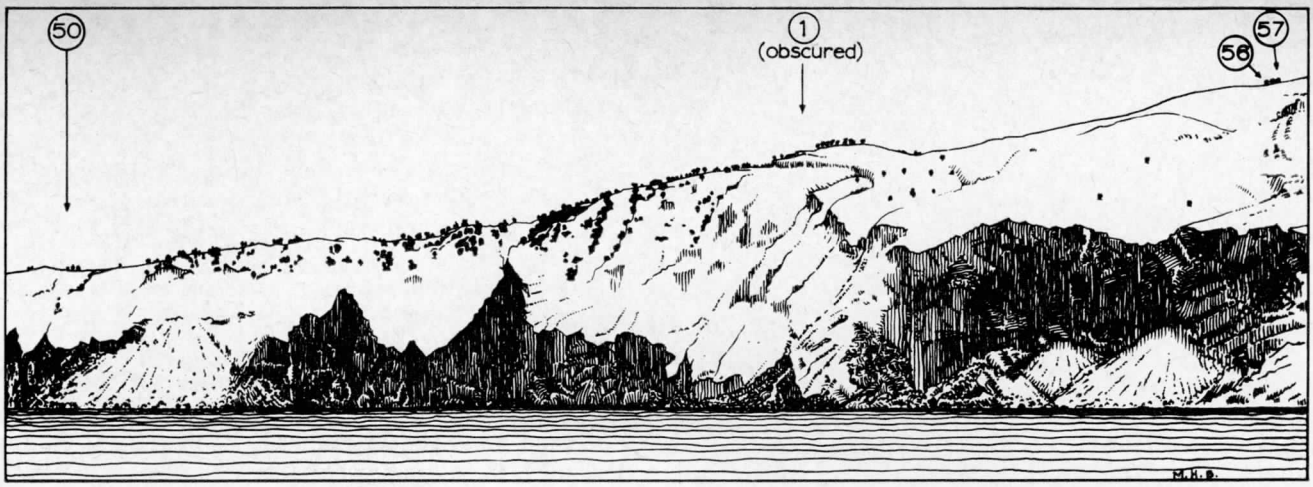

Fig. 1.—Panoramic view from northwest, showing distribution of nearly all the pines on Guadalupe Island. (Drawn from Kodachrome transparencies of R. V. Moran, dated 17 April 1957.) Numbers 1 and 50 indicate the highest and lowest trees collected by Moran in 1958. Numbers 56 and 57 indicate the southernmost grove (3 trees) of the four high elevation groves (15 trees total).

able on specific characteristics of the donor trees, and with one exception, there was no apparent effort to collect from trees particularly suitable for forestry purposes.

Fielding (*8*, *9*) and Bannister (*2*) stressed the importance of obtaining a systematic sample of seed from the pines of these islands, for extensive testing of their adaptability under plantation conditions, and for their introduction into the gene pool of Monterey pine on an experimental basis. Therefore, the New Zealand and Australian governments, respectively, requested a systematic, and a selected (from the "best trees"), sample of seed from the pines of Guadalupe Island. In 1958, Dr. Reid Moran of the San Diego Natural History Museum, with the help of Dr. Ira Wiggins and Mr. Wallace Ernst, collected cones from 50 pines. This collection was made over most of the main population of pines on Guadalupe Island, from elevations of about 480 to 880 meters (Fig. 1). However, it was limited to trees whose cone-bearing branches extended to within five meters of the ground, the height which could be reached with a pole pruner. Furthermore, they did not collect from the trees which are 1.5 to 3 kilometers southwest of the main population, growing at elevations from 1,120 to 1,160 meters. Since the highest mainland Monterey pines grown at a maximum of only 300 meters elevation, these few high-elevation Guadalupe Island pines are of particular interest (Fig. 2).

In 1964, the New Zealand Forest Research Institute arranged an expedition to the Mexican islands. Since interest in planting Monterey pine in California has been increasing, it became important to obtain complete samples of the pines from both islands for testing under California conditions. Therefore, we planned a combined expedition to make extensive collections from the pine populations on Cedros Island, and to supplement Moran's collection from Guadalupe Island with cones from the higher-elevation trees, and from ently out of reach of Moran's pole pruner.

This paper describes the location, environment, numbers, and gross physical characteristics of the pines on these two islands. The locations of the known plantations of Cedros and Guadalupe island pines are also reported below.

Guadalupe Island

Guadalupe Island is a Mexican possession, located in the Pacific Ocean approximately 250 kilometers off the shore of Baja California and 500 kilometers due south of Los Angeles. It is a volcanic island (*7*), rising approximately 5,000 meters from the ocean floor. The highest point on the island, Mount Augusta, is 1,298 meters above sea level. The oldest lava flow dated on Guadalupe Island indicates an age of 7,000,000 years. There is no evidence that the island has been submerged since that time, and furthermore, no reason to think it has even been connected to the mainland.[1]

The particular combination of winds, ocean currents, and topography on and near the island result in both summer and winter fogs over and among the pines (*30*). These fogs protect the pines from the heat and summer drought characteristic of most of the island. Because of the fog drip (*10, 26*), rainfall data (which are not available) would be difficult to interpret relative to requirements of the pines. In some years there is an abundance of rain; in others, no rain as such occurs (*30*).

Hemsley speculated that the climate of northern Guadalupe Island is colder than that of the coast regions of central California (*14*). Relatively few scientists have visited the island during the winter months, and even fewer have remained for the entire season. Therefore, it is reasonable to assume that moderately severe winter conditions are not infrequent, since two heavy snowfalls have been reported, and several accounts mention frosts or below-freezing temperatures (*24, 30*). We also briefly experienced freezing rain at our camp 300 meters below the highest pines in late February 1964. It will be interest-

[1] Personal communication, Drs. Carl Hubbs and A.E.J. Engel, University of California at San Diego. January 1966.
[2] Personal communication. December 1965.

Fig. 2.—The highest tree on Guadalupe Island (elevation 1,160 meters). Its diameter was 164 centimeters, and its height only 13 meters. The outer 18 cm. of the increment core had 80+ rings. Notice the snag visible just below the left side of the tree. There were other indications in this area that a forest once occupied the site. However, in March 1964, this tree's nearest living neighbor was over 400 meters distant.

ing to determine whether Guadalupe Island pines are more cold-tolerant than Monterey pines, which only rarely experience such weather conditions in their native range.

Goats were released on Guadalupe Island some time before 1865 (but probably after 1793), in order to provide fresh meat to ships short of provisions without risk of desertion by the crew (*14, 19, 30*). In 1865, a commercial angora goat enterprise was begun on the island (*30*), and in subsequent years, many cargoes of goat skins and tallow were shipped to San Diego (*14*). However, in 1884, the Mexican government stationed soldiers on the island to prevent wholesale slaughter of the goats (*12*). Additional attempts to harvest the goats were made in 1900, during World War I, and in 1930 (*17*). These ventures were all unsuccessful, and generally short-lived. The goat population has repeatedly exceeded the carrying capacity of the island, causing severe damage to the vegetation, and extinction of several species of plants recorded by Palmer as abundant in 1875 (*10, 19, 24, 26, 30*).

The island has been briefly inhabited by shipwrecked sailors, an expelled Mexican governor and his family, goat hunters, goatherders, and army garrisons (*12, 17, 30*). However, for all practical purposes, the island has been and remains uninhabited, although the Mexican government currently maintains a small weather station on its southern shore. Nelson summarized the various observations of early visitors to Guadalupe (*26*). A general description of more recent conditions on the island may best be gained from Howell's account of his visits (*16*).

We were able to spend only two short days (March 1 and 3, 1964) in the pine stands. We hiked the length of the population, counting and mapping the living pines as best we could. We were hampered by occasional driving rain, much blowing mist, and occasional heavy fog. Therefore, our pine census, particularly of those trees on the lower reaches of the cliffs and canyons, is approximate. The pines are restricted to the northern part of the island, north of Mount Augusta, on the top and windward side of the main ridge, which is a remnant of a great crater half-eroded by the sea (*24*). They occur over an elevational range of approximately 800 meters, from about 300 to 1,160 meters.

We observed only 383 living pines on the island (Fig. 1). Details of the 1964 distribution of pines on the island are given in Bannister's report (*3*). It was clear that these trees were the survivors of a much larger, or at least much denser, population. The early accounts of the island all mention general goat damage and discuss the scattered pine trees, described by Brown in 1906 as in a condition of "fast decay" (*10, 12, 26, 30*). It is not clear from any of these accounts how large the pine population actually was, nor how much damage to living trees was in evidence in the late 1800's. Franceschi reported evidence of one or more large fires prior to 1893, which carried from the pine forests into the palms (Figs. 3 and 4) (*11*). The stands of pines in their present condition could not possibly generate such a fire.

Apparently all seedling and sapling trees were killed shortly after the goat population first reached the carrying capacity of the island, and the goats, perhaps aided by mice (*10, 12, 26*), have since prevented effective regeneration of the pines. Two small trees about five centimeters in diameter and three meters tall were growing on a rocky crag, and 25 yearling seedlings were observed on the lee side of the ridge in the lower part of the population. The two larger trees apparently were inaccessible to the goats, and the seedlings germinated and grew during a low ebb in the goat population. Moran[2] felt that the goat population had been low for the past two or three years, as evidenced by the appearance on the slopes of various plants which were previously confined to cliffs. We saw no more than 200 goats during our five days on the island. Mason[3] recalled a much denser goat population during his visit in April 1925, stating he was never out of sight of at least 200 goats at any one location. Furthermore, we saw neither mice nor cats, although Greene reported an abundance of both (*12*).

We conducted two levels of sampling on Guadalupe Island. 1. For each of 13 trees spaced over the length of the population, we attempted to collect needles, resin, and five cones, and recorded data on height, diameter, elevation, and location. Due to the limited time we were able to spend in the pine population, this level of sampling was completed for only three trees. All data were recorded for the remaining 10, but we failed to obtain either sufficient needles, resin and/or cones to complete the sample as desired. 2. We collected cones from an additional 64 trees, with no supporting data from the parent trees other than general location. A single cone was picked

[3] Personal communication. May 1965.

Fig. 3.—The region including tree 1 (Fig. 1). Some of the better trees on Guadalupe Island are in the left-center of the picture, just above the cliff edge. The rounded dark trees are island oaks, (*Quercus tomentella*) and a grove of Guadalupe Island palms (*Erythea edulis*) is most easily seen just above the cliff on the right of the picture. The first wisp of afternoon fog is forming in the center of the picture. (Courtesy Dr. Reid Moran. Picture taken April 17, 1957.)

from about every third tree which was easily accessible, and single cones were shot from several of the better-formed, less-accessible trees.

Three trees in the broad grassy area below 1 (Figs. 1 and 3) are, respectively, the best-formed tree seen on the island (112 cm. diameter breast height and 27 meters tall), the tallest tree measured on the island (33 meters), and the largest-diameter tree measured on the island (211 cm. d.b.h.). In 1931, Howell measured a tree on Guadalupe Island which was 272 cm. in diameter (*15*). It is uncertain whether we missed this outstanding specimen, or whether it has died and fallen in the intervening 33 years. Howell[4] indicated that he measured the circumference with a string near the ground line, which could account for the difference. Even the 211 cm. tree is larger than the largest native Monterey pine we have measured (183 cm. d.b.h., above Ano Nuevo Point, in the northern population of Monterey pine), and dwarfs the largest recorded native bishop pine, a 147 cm. stump diameter measured in Humboldt County by Metcalf (*23*).

It had been our intent to collect from the more inaccessible trees in the region 1-50. However, winds were so high during the time we were in the area that we were unable to either reach or shoot cones from well-pruned trees. Therefore, it is likely that our collection (from 1-50) largely repeats part of the 1958 Moran collection.

Cedros Island

Cedros Island lies about 30 kilometers northwest of the southern point of Sebastian Vizcaino Bay, in Baja California, approximately 300 kilometers east-southeast of Guadalupe Island. It resembles Guadalupe Island both in size and in general shape. It is an arrowhead-shaped island, approximately 32 kilometers long and 15 kilometers wide at its widest point. The fishing village of Cedros, a community of about 2,000, lies southeast of Cedros Mountain on a good harbor.

Cedros Island is near the southern edge of California's winter storms, and the northern edge of southern Baja California's tropical summer rains. However, the rains are unreliable in both seasons, and in some years little or no rain occurs at the village. As on Guadalupe, fogs are prevalent in all seasons (*13, 27*). Unlike Guadalupe, its soils are mostly derived from sedimentary and metamorphic rocks, with some granite on the northern ridge (*13, 26*). It has been connected to mainland Baja California in the recent geologic past, and at present appears as a disjunct extension of the southern headland of Sebastian Vizcaino Bay (*27*).

The pines occur in two major populations, inland on the central part of the island and on the northern part of the island. The lower elevational limit of the pines (275 meters elevation) is similar to that on Guadalupe Island. Unlike on Guadalupe, the highest pines grow at only 640 meters, although nearby mountains are over 1,000 meters high. It may be that they are restricted to middle elevations because that is where the maximum concentrations of fog occur on Cedros. Hale observed mildly foggy days when each pine grove was covered by a separate cloud, and the desert between the groves was exposed to the clear sky (*13*). While there are goats and many other animals on Cedros (*24*), there is no evidence of serious animal

[4] Personal communication. June 1965.

Fig. 4.—The lower part of Guadalupe population as seen from the lee side. (Courtesy Dr. Reid Moran. Picture taken April 13, 1948.)

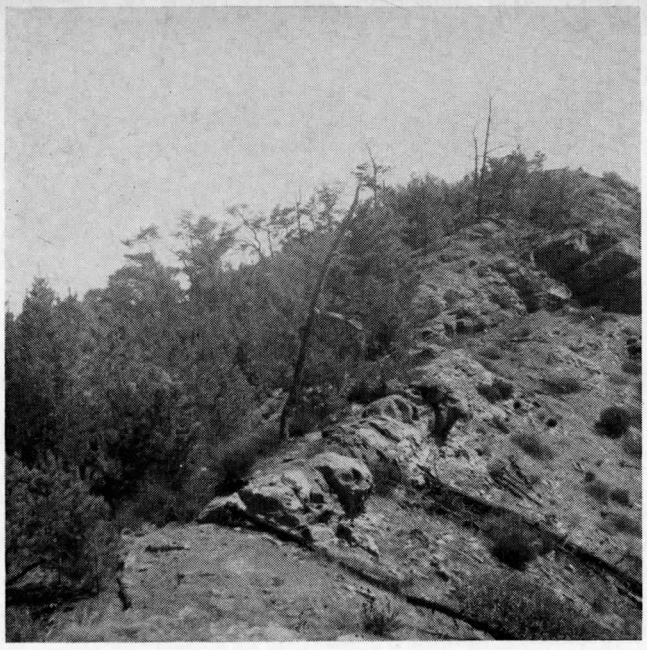

Fig. 5.—View along the ridge top of the southern population on Cedros Island, showing the dense reproduction, scattered mature trees, and the restriction of the trees to the windward side of the ridge.

damage to the pines, nor any apparent danger of extinction as on Guadalupe Island.

As on Guadalupe, the southern population is primarily distributed along the windward side of the main ridge running north from Cedros Mountain. The main stand was made up of very dense reproduction, apparently established following several fires. A few hundred mature trees occurred in groups here and there throughout the stand, especially on the lower windward parts of the stand where they probably escaped the fires (Fig. 5). An outlier east of the main stand was made up exclusively of even-aged dense reproduction. Three small groves 3.5 kilometers north of the main population were made up primarily of mature trees with little reproduction. We estimated that 35,000 or more trees (disregarding the extremely dense reproduction on some areas) occupied an area of about 50 hectares in the southern population.

The northern population is distributed in the shape of a large "F" with a dot above it (Fig. 6). The stem of the "F" and the dot above the "F" are composed of trees overlooking the windward shore of the island. The two arms of the "F" extend inland along the ridges around a major canyon where gold and copper mines were operated in the early 1900's (*27*). Additionally, many trees occur on subsidiary ridges to the floor of the canyon. The northern population had more mature trees, and the reproduction was older and less dense than in the southern population. The outlying stands have escaped recent fires and were made up almost entirely of mature trees. We estimated that 50,000 trees occupied an area of about 100 hectares in the northern population. See Bannister's report for details of these populations (*3*).

Although Durham commented that no trees in the northern population appeared taller than 21 meters nor more than 61 cm. in diameter (*5*), we found several trees in excess of these dimensions. The tallest tree measured in the northern population was 29.5 meters tall and 57 cm. in diameter, and the largest diameter measured was 77 cm. d.b.h. on a tree 16 meters tall. One taller tree was observed in the southern population (32 meters tall and 65 cm. in diameter), but the maximum diameter observed there was only 69 cm. d.b.h.

The largest and best-formed trees in the southern population, and the tallest tree on the island, were on a relatively mesic site with deep soils in a stand extending from the ridge top at 520 meters down a moderate slope to 460 meters. The largest and best-formed trees in the northern population occurred on a similar relatively mesic site near the top of the main ridge. The only all-aged stand seen on the island occurred on the northern point of the island, on what was perhaps the most mesic site supporting pines on Cedros. Several very poor sites, supporting slow-growing stunted trees, were observed in both the northern and southern populations.

The presence of fog seems to be critical for the growth of pines on both islands as trees are restricted to ridges and windward slopes on Guadalupe (Figs. 1, 3, and 4) and southern Cedros (Fig. 5). On northern Cedros most of the pines follow the same pattern, and those pines growing in the lee of the main ridge are restricted to moist canyon slopes (Fig. 6).

Unlike on Guadalupe, we were able to spend eight days among the pines on Cedros Island in relatively good weather. Therefore, the Cedros Island sample is both larger and more complete than the sample from Guadalupe Island. For each of 30 trees spaced over the distribution of each of the two populations, we collected needles, resin, and 12 cones; and recorded data on height, diameter, radial growth rate, elevation, and location. Wood samples were taken from every second tree within this 60-tree sample. We collected two cones from each of 40 additional trees, 20 in each population, and also recorded data on height, diameter, radial growth rate, elevation and location. These 40 additional trees were not evenly spaced throughout the populations. They were generally the better-formed, larger trees in an area, although in some cases they were chosen for some other characteristic. For example, a few very young trees were chosen because of precocious cone production, and a few suppressed trees were purposely selected close to selected dominant and codominant trees. Since 12 cones were required from each tree of the main sample of 60 trees, it was felt that this might be biasing the collection toward heavy cone-producers. Therefore, the additional 40-tree sample was consciously meant to offset this bias.

On both Cedros and Guadalupe Islands, cones were generally collected from trees that were on or near the ridge top. This was in part an operational consideration, as working the cliffs was both dangerous and time-consuming. However, we feel that seeds from these cones are an adequate sample of the entire population, as the expected pollen-flight pattern is

from the lower reaches of the populations up to the ridge with the prevailing winds. Therefore, in view of the number and distribution of trees sampled, the seedling offspring of these trees should contain the majority of genetic variation present in the pines of Cedros and Guadalupe Islands.

Outplantings and Seed Orchards

The oldest verified Guadalupe Island pines growing off of Guadalupe Island are four large sexually mature trees at the abandoned U. S. Horticultural Field Station near La Jolla, California. These were established from seed collected by Guy Fleming on the 1931 Allan Hancock expedition to Guadalupe Island. A subsample from 18 trees of Moran's 1958 collection was planted in the Australian Capital Territory in 1959 (*9*). In a prior visit, Moran, Dr. Gene Newcomb (then a graduate student at the University of California at Berkeley), and Dr. C. H. Muller (of the University of California at Santa Barbara), collected cones from several trees on Guadalupe Island in 1957. Four trees were established in 1961 at the Institute of Forest Genetics (Placerville, California) from seed collected near 800 meters elevation by Moran and Muller in 1957. An additional 10 trees from Moran's 1957 collection, of uncertain origin within the Guadalupe population, were established along with the four trees of relatively certain origin. Newcomb's 1957 collection was made in the upper part of the main population, from about 700 to 880 meters elevation. Records at the Institute of Forest Genetics indicate that Newcomb's collection was sent to L. W. Bryan (Hilo, Hawaii), A. Juriaanse (Union of South Africa), and the Director of Forestry (Southern Rhodesia) in 1960. In 1962, 118 seedlings from three trees of Moran and Newcomb's 1957 collection were planted in the New Zealand Forest Research Institute arboretum at Whakarewarewa. Seeds from Moran's 50 families collected in 1958 were sown at the New Zealand F.R.I. in 1963.

Dr. S. B. Benson (of the University of California at Berkeley) collected cones from several trees in the northern part of the main northern population on Cedros Island in 1947. Twenty-four seedlings from this collection have been growing in the Australian Capital Territory since 1954 (*9*). Also, one tree is growing on Dr. Benson's property in Marin County, California. In 1963, the Institute of Forest Genetics planted seven seedlings from cones of a single tree high in the southern Cedros Island population, collected by Muller in 1960. To our knowledge, this survey includes all the pines of Cedros and Guadalupe Island origin planted out of their native range as of 1963.

In New Zealand, seeds which we collected on Guadalupe from five trees above 1,100 meters elevation were sown in 1964. These five families were added to Moran's 50 1958-collection families. Seeds from the 60 families of our main sample taken on Cedros Island were also sown in 1964. As of 1965, about 1,100 Guadalupe Island pines and 900 Cedros Island pines have been outplanted in randomized experimental designs in compartments 1,333 and 918 of the Kaingaroa State Forest.

In California, living seedlings were obtained from 76 of the 77 open-pollinated families from Guadalupe Island, and from 98 of the 100 families from Cedros Island. Plantations have been established in three locations to serve as test sites and seed orchards. One plantation of each origin is on the Redwood Experimental Forest (U. S. Forest Service) in Del Norte County. The second pair of plantations is on Jackson State Forest (California Division of Forestry) in Mendocino County. The third pair of plantations is on the Russell Reservation (University of California), 16 kilometers east of Berkeley. Two seedlings from each family have been planted in each of the three plantations. Separation between the Cedros and Guadalupe plantations at each of the two northern locations is sufficient so that cross-pollination between plantations will be negligible. These plantations are at a sufficient distance from sources of Monterey and bishop pine pollen so that pollen contamination from relatives of

Fig. 6.—Aerial view of the northern Cedros population, looking south. NPQRUW: Main ridge line 8.8 km. long, with outlying stands at N (600 meters from 0) and at UVW (2,300 meters from R). The populations on the two interior ridges (SP and TQ) are 1.4 and 1.3 km. long, respectively. Y: Canyon with extensive mining scars. The trees grow from a lower elevation (near Y) of 275 meters to the peak near S at 640 meters. Note the fog drifting against the windward slopes and flowing through the saddle (UR).

Cedros and Guadalupe Island pine will also be negligible. Thus, future mass-collections of seed from these plantations will provide inexpensive unselected seed of Cedros Island pine and Guadalupe Island pine for either further testing or production plantations.

Discussion

A symposium was recently held on the biology of the California off-shore islands. One of the clearest generalizations which developed from discussion of the diverse organisms studied, was that many of the populations of plants and animals on the islands seem to be relict in nature when compared to related populations on the mainland (*28*). In other words, the island populations were not rapidly diverging either from each other or from the mainland forms. Rather, they are generally much more like related fossil forms than are the mainland populations, which have been evolutionarily more active.

Mason has investigated Pleistocene deposits at Carpinteria (34°20′ N latitude) and at Tomales Bay (38°N). At Carpinteria, the *radiata*-type cones outnumbered the *muricata*-type cones "considerably," yet there was a marked preponderance of two-needle fascicles among the abundant needles in the deposit, outnumbering the three-needle fascicles about eight to one (*20*). Similarly, at Tomales Bay, only seven *muricata*-type cones were found among several hundred *radiata*-type cones, yet there was a two-to-one preponderance of two-needle to three-needle fascicles (*21*). Modern *P. muricata* has its needle bundles typically in two's, while *P. radiata* tends to have a majority of three's. However, the Cedros and Guadalupe Island populations may be characterized by having *radiata*-type cones, but needle bundles in two's. Perhaps these pines, like many of their associates, have existed in relatively safe and buffered sites on these two islands, and have diverged relatively little from their Pleistocene ancestors compared to their mainland relatives (*20*).

The modern relationship of the pines of Cedros and Guadalupe Islands to bishop pine, Monterey pine, and island pine (*Pinus remorata* Mason) (*1, 20, 22*), and to each other, may be investigated by common-garden experiments. These are planned for the near future, and will include seedlings from our 1964 Cedros and Guadalupe Island collections, and from all other native populations of bishop, island, and Monterey pine. After these experiments are established, unused seeds will be available to interested persons for testing in their localities. In addition, subsamples of the collected seeds from Cedros Island were deposited with the Mexican Forest Research Institute at Coyoacan in 1964.

As a final note: Red-band needle-blight (Scirrhia pini or Dothistroma pini) *looms as a serious threat to Monterey pine throughout the world. Preliminary tests indicate that seedlings from both Cedros and Guadalupe Islands are much less susceptible to this disease than seedlings from the mainland Monterey pine populations* (4). *If the red-band needle-blight continues to be a serious disease, and if the observed difference in susceptibility proves out, the pines of Cedros and Guadalupe Islands may rapidly take their place among the most important trees in the world.*

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Acknowledgements

We are grateful to Richard and Eleanor Dwyer, and the crew of the research vessel *Gringa,* for transportation to Guadalupe and Cedros Islands and for their helpful interest in the expedition; to E. W. Scripps and the crew of the yacht *Betty Jeanne,* for their ready and understanding assistance in returning us from Cedros; and to Francisco Munoz, for his accommodation to our schedules on the flights to and from Cedros, and assistance in aerial reconnaissance of the Cedros Island stands. Drs. Yale Dawson and Reid Moran of the San Diego Natural History Museum, Carl Hubbs of the University of California at San Diego, and David Jameson of San Diego State College were generous with time, hospitality and advice during the preparations for the expedition. Reid Moran has also contributed additional advice and information during the preparation of the manuscript. Ib Thulin, of the FAO, labored long and patiently to secure the permits necessary for collection and export of the samples. Dr. Enrique Beltran of the Mexican Forest Service, and General Jose Melendez Martinez Ordaz of the 5th Infantry Battalion, Baja California, interceded in our behalf when difficulties arose. The devoted and imaginative labors of our guide and colleague, Jeronimo Barajas-Maciel, and the warm hospitality and services performed by Don Francisco Amaya and our many friends on Cedros Island, contributed largely to the effectiveness of our work on Cedros and our pleasure in doing it.

HOW SERIOUS IS RABBIT DAMAGE ON LOBLOLLY PINE SEEDLINGS?

ABSTRACT.—There was no great difference in survival rate and no important difference in growth rate, in loblolly pine seedlings clipped by rabbits and these not clipped.

THREE large study plots, containing about 1400 trees each, were established in a January 1959, planting of loblolly pine (*Pinus taeda* L.) in east Texas (*1, 2*). Almost immediately after the seedlings were planted, some were neatly clipped about 0.2 feet above the ground. These seedlings were considered to be destroyed, since no green leaves remained on the stubs. The plants appeared to be injured by rabbits (*3, 4, 5),* as many cottontails *(Sylvilagus floridanus alacer* Bangs) were noted in the plantation.

When the seedlings were remeasured in January 1960, many of the presumed dead, clipped ones were found to have sprouted and were growing vigorously. Subsequent measurements in 1961, 1962, and 1963 revealed that practically all clipped seedlings surviving the first year continued to grow as well as undamaged ones. Analyses of measurements gave the following results (Table 1):

1. Seedlings less than 6 inches tall were more apt to be clipped than larger ones.

2. Clipped seedlings survived nearly as well as unclipped ones.

3. After four growing seasons, the height of clipped seedlings was about one foot less than that of the unclipped. Statistically, the difference in height between clipped and unclipped trees after four years was significant on two plots and not significant on the third.

4. Growth rates of clipped and unclipped seedlings were about the same.

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Table 1.—Survival and Growth of Loblolly Pine Seedlings in a Texas Plantation with Rabbit Damage

Item	PLOT 1		PLOT 2		PLOT 3		ALL PLOTS	
	Clipped	Not clipped	Clipped	Not clipped	Clipped	Not clipped	Clipped	Not clipped
Number trees Jan. 1959	42	1424	65	1484	42	1456	149	4364
Number surviving Jan. 1963	23	1157	32	883	29	745	84	2785
Percent survival	55	81	49	59	69	51	56	64
Avg. ht. in ft. Jan. 1959[1]	.53	.81	.59	.73	.44	.77	.52	.77
Avg. ht. in ft. Jan. 1963[2]	7.59	8.22	5.33	6.84	6.39	7.74	6.32	7.65
Ht. growth in ft., 4 seasons[3]	7.34	7.41	5.08	6.12	6.14	6.97	6.06	6.88

[1] Statistically, there was a highly significant difference between the average height and the lesser height of seedlings to be later clipped in each of the plots. After rabbit damage, the clipped trees were only about 0.2 feet tall.
[2] Differences in plots 2 and 3 were highly significant, in plot 1, not significant.
[3] For clipped trees growth was calculated from 0.2 feet height in 1959.